DOE/OE Transmission Reliability Program

Measurement of Phasor-like quantities

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CERTS

CONSORTIUM FOR ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

Project Objective

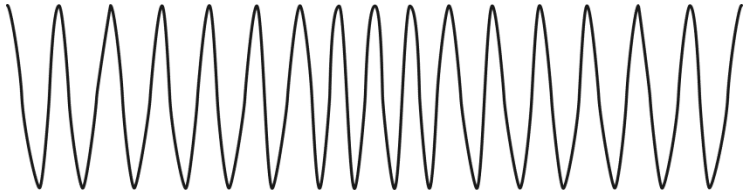
- PMUs do not always report same thing
- Some users unhappy with frequency and ROCOF outputs
- New method of measurement shows promise to solve these problems

- Objective was to advance the work to get it commercialized

  This seemed to hinge on a definition for “frequency”

Why?

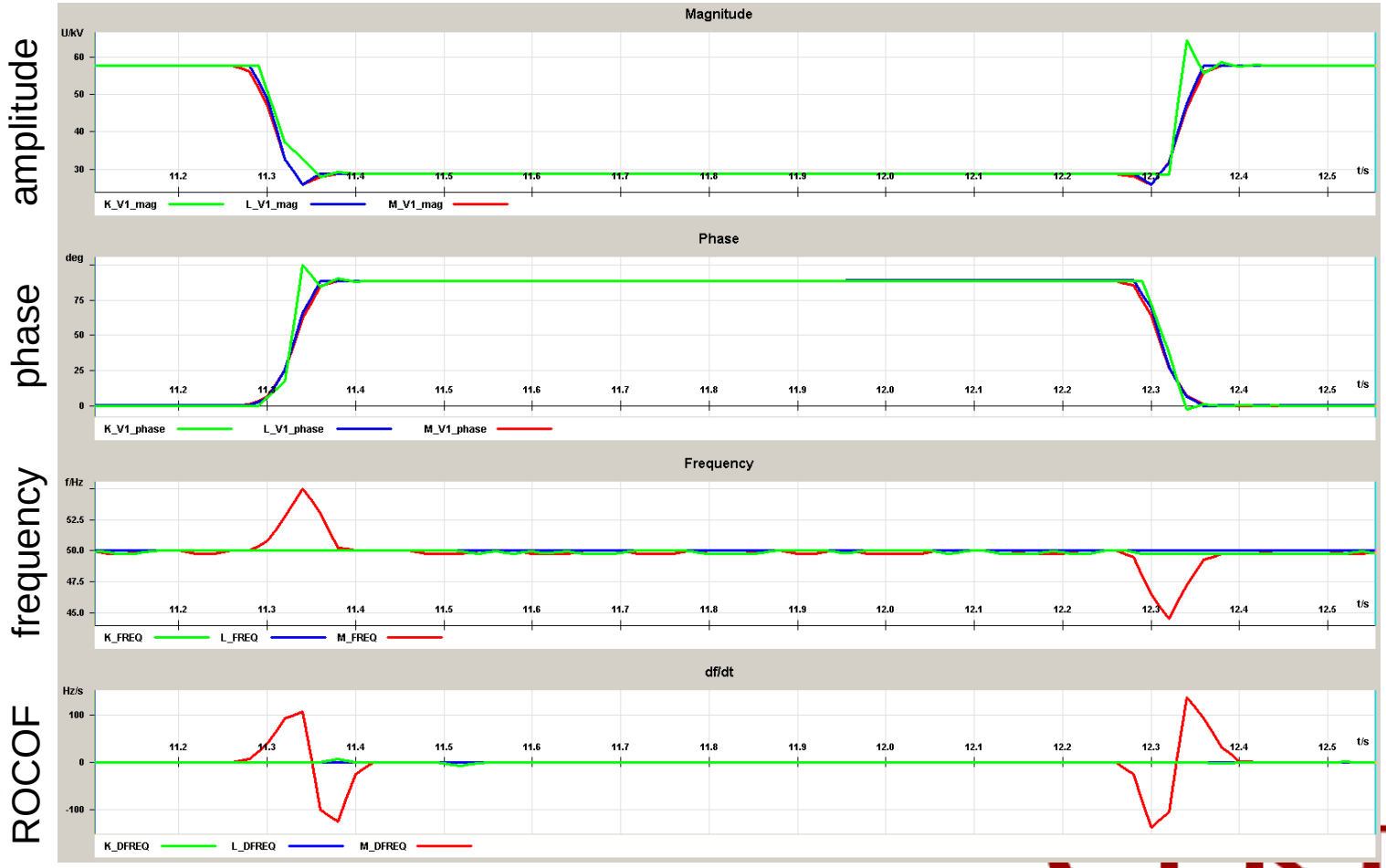
- How to define “frequency” when “frequency” is changing?
- “White papers” and e-mails
- Epistemology problem?



- The effort to define “frequency” has led to
  - A new way of solving the PMU problem
  - A new way of thinking about measurement

Example

- Three PMUs compared: 10% drop in amplitude, 90 degree phase shift



Project result

- Originally:
  - A new way of solving the PMU problem

- Now also:
  - New way of thinking about measurement
  - General. This could represent a significant shift in the science of measurement

Remainder of presentation considers both aspects

Project result (PMU method)

- Standard says this is the equation of a phasor

$$x(t) = X\cos(\omega t + \varphi)$$

- and defines frequency as

$$f = \frac{d\Psi}{dt}$$

- "Old" method treated only phase as "primitive"
  - Found frequency as derivative, requiring two adjacent sets of measurements
  - Suffered from noise sensitivity
  - And suffered either
    - Data skew or delay
    - or
    - *Greater* susceptibility to noise

Project result (PMU method)

- A new way of solving the PMU problem
  - Treats the measurand as a set of "primitive" quantities (amplitude, frequency, phase, ROCOF)
  - Finds values for each of these parameters *within a single measurement window*
- New method says this is the measurand:

$$x(t) = X\cos\{(\omega + C_\omega t)t + (\varphi + C_\varphi t)\}$$

$$= X\cos\{(\omega + C_\varphi + C_\omega t)t + \varphi\}$$

- Four "primitives" are X, $(\omega + C_\varphi)$, φ and C_ω.

Project result (PMU method)

- We started by restricting our view to just two cycles.
- With *clean* (synthetic) data, we can find
  - Amplitude within about 0.01%
  - Frequency within a mHz
  - Phase within small fraction of a degree
  - Rate of change of amplitude within a few percent
- *But rate of change of frequency was better with four cycles*

Project result (PMU method)

- We have been talking to Macrodyne re adopting
- Though new method better, that has not been shown with real-world signals
- Paper in preparation
- Recently problems with phase noise on power system are being discussed in the community
- Speculation: is phase noise so large that even a “perfect” PMU could not make a useful measurement?

Deliverables (PMU method)

#	Milestone/Deliverable	Target Date
1	Demonstrate improved performance with real-world signals	12/31/2015
2	Final report on estimation method, including demonstrated results, and further IEEE paper (PES)	4/30/2016

Risk Factors

The problem is getting point on genuine point-on-wave data from power system

Once that is available, what will the phase noise be?

Could it be taken as universally representative?

Getting even one sample is proving challenging – yet more will be needed to allow general statements

Looking Forward

- Could be that new method overcomes phase noise problem – *but not proven*
- Aspects of new method are finding way into the upcoming IEC standard (Kirkham is a U.S. representative to IEC)
- Still hopeful of commercializing method

Project result (Framework)

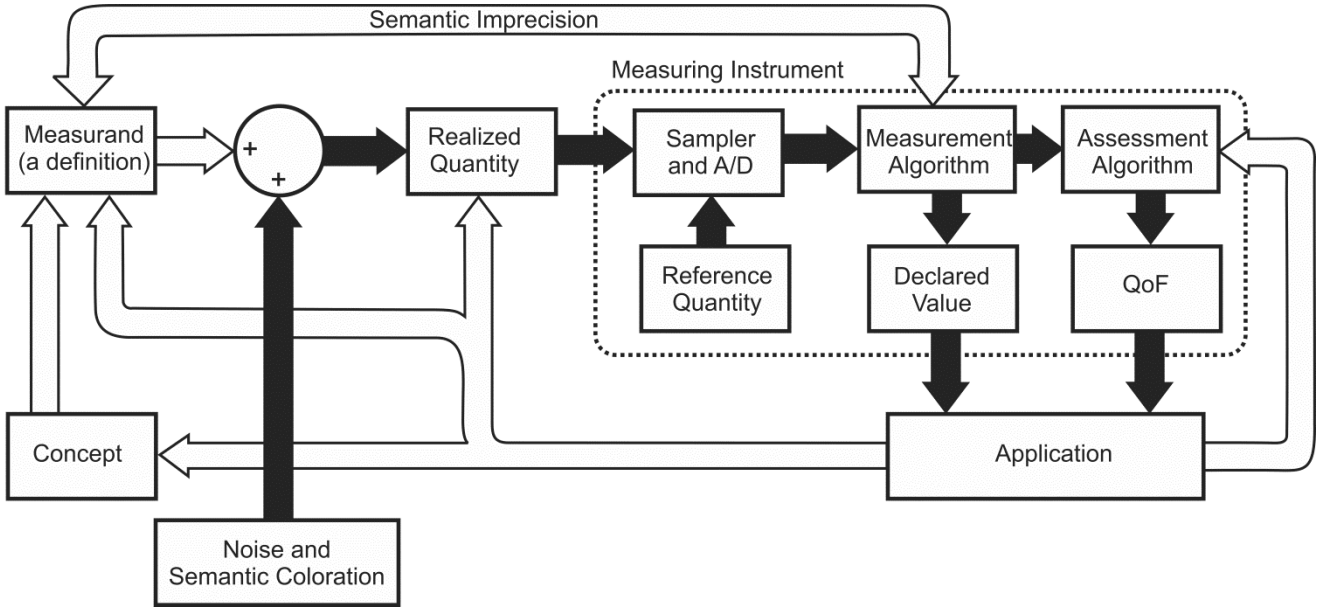
- Regards measurement as process of solving equation

- Equation is measurand
- Equation provides the syntax, the *numbers* are the semantics

- Measurand should be expressed in spoken language *after* mathematical definition agreed to
  - "frequency" is just a term in an equation
  - The bounds on the method are fixed by the application

- But there is so much more . . .

Project result (Framework)



- Measurement framework is rich source of future development, needs to be more widely published

Deliverables (Framework)

This work is beyond the scope of the Plan, therefore no related deliverables yet in Plan

#	Milestone/Deliverable	Target Date
1	Report to DOE describing framework	February 2015
2	Paper submitted to *Metrologia*	10/16/2015
3	Series in *Instrumentation and Measurements*	12/18/2016
4	Final Report	1/29/2016

Risk Factors

The risk is about dates

We can write the papers and submit them – but (with these target publications), we have no experience of how long the process takes

Follow-on into FY16

Early thoughts:

(1) Continue to move these ideas into IEC standard

(2) Revisit IEEE standard if new method solves ROCOF problem!

(3) Demonstrate a QoF algorithm (eg r^2) in a PMU

(4) Investigate “prediction” algorithm

Look at Viterbi and alternatives